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A DESCRIPTION OF A New PYROMETER, WITH A TABLE of EXPERIMENTS Made therewith.

By J. SMEATON, F. R. S.

AS it may tend to illuftrate the following account, it may not be improper to make mention of the properties, that a complete inftrument, for meafuring the expanfions, that metalline bodies are fubject to by heat and cold, ought to be endowed with.

And, firft, fince the quantities of thofe expanfions muft be proportionable to the length of the bar

to be meaſured; the longer the bar, the more ſenſible the expanſion: And therefore ſuch a conſtruction is beſt, as (*cæteris paribus*) will admit of the longeſt bar.

Secondly, That the ſcale, whereupon thoſe minute alterations are to be meaſured, ought to be, at leaſt, ſo large, that the ſmalleſt change in the length of the bar, which the inſtrument is capable of being with certainty affected with, ought to be perceiveable thereon.

Thirdly, As the ſame change, with reſpect to the poſition of the index and ſcale, will enſue, upon the ſuppoſition, that the materials, compoſing the inſtrument itſelf, are expanded in a certain degree, and the bar applied to be meaſured remains unchanged in its length; as if the inſtrument were ſuppoſed to ſuffer no expanſion, and the bar to be meaſured were ſuppos'd to expand in the former degree: It is therefore neceſſary, that, in the making uſe of an inſtrument of this kind, the materials, of which thoſe parts are compoſed, upon which the meaſure depends, and which may be called the baſis thereof, ſhould be ſubject to no expanſion or contraction during ſuch trial, or that the expanſion or contraction thereof ſhould be capable of being known, and accounted for.

Fourthly, That as all bodies grow ſtill longer by the application of a greater degree of heat; to compare the expanſions of different bodies, we ought to have ſome method of heating them in the ſame degree, notwithſtanding their difference of texture, ſpecific gravity, &c.

Fifthly,

Fifthly, The ſeveral parts, upon which the meaſurements depend, ought to be ſufficiently large, to be themſelves actually meaſured; that not only the proportions of increaſe of length in different metals, by the ſame degrees of heat, may be known; but alſo the quantities of thoſe expanſions, in real meaſures: Or, in other words, the proportions, that their increaſe of length, between certain degrees of heat, bears to the length of the bodies: By which means, we are enabled to aſcertain the changes, that bodies undergo in their dimenſions by the application of any given degrees of heat.

With reſpect to the firſt property, this inſtrument is capable of receiving a bar 2 feet 4 inches long, and might be made capable of receiving bars of a much greater length, of ſome kinds of materials, but not of others; on account of the flexibility brought upon them by a degree of heat not greater than boiling water.

The meaſures taken by this inſtrument are determined by the contact of a piece of metal with the point of a micrometer-ſcrew. The obſervation is the beſt judg'd of by the hearing, rather than that of the ſight or feeling. By this method I have found it very practicable, to repeat the ſame meaſurement ſeveral times, without differing from itſelf above one twenty-thouſandth part of an inch. This principle of determining meaſures by contact is not wholly new; but has been employ'd on ſeveral occaſions, as I am inform'd, by the late Mr. Graham: But the preſent manner of applying thereof, I believe, is ſo; and the degree of ſenſibility ariſing therefrom exceeds any

thing I have met with. As the method will eafily appear by the draught (fee *Plate* XXI.), I fhall avoid a farther defcription of it in this place *.

As no fubftance has hitherto been difcover'd in nature, that is perfectly free from expanfion by heat, I chofe to conftruct this inftrument in fuch a manner, that the bar, which makes the bafis of the inftrument, fhall in each experiment fuffer the fame degree of heat, as the bar to be meafur'd: Of confequence, the meafures taken by the micrometer are the differences of their expanfion. The expanfion then of the bafis between two given degrees of heat being once found, the abfolute expanfion of any other body, by adding or fubtracting the difference to or from the expanfion of the bafis, according as the body to be meafur'd expands more or lefs than the bafis, will alfo be determin'd.

When the inftrument is made ufe of, it is immerg'd, together with the bar to be meafur'd, in a ciftern of water; which water, by means of lamps apply'd underneath, is made to receive any intended degree of heat, not greater than that of boiling, and thereby communicates the fame degree of heat to the inftrument, the bar, and to a mercurial thermometer immerg'd therein, for the purpofe of afcertaining that

* I have lately feen an inftrument at Mr. Short's, made by the late Mr. Graham, for meafuring the minute alterations, in length, of metal bars; which were determin'd by advancing the point of a micrometer-fcrew, till it fenfibly ftopp'd againft the end of the bar to be meafur'd. This fcrew being fmall, and very lightly hung, was capable of agreement within the 3 or 4000th part of an inch.

that degree. That this may be truly the cafe, the water fhould be frequently ftirr'd, that there may be no difference of heat in the different parts of the water: This being done, the height of the quick-filver appearing ftationary, the contact with the fcrew of the micrometer alfo remaining the fame, for a fpace of time, it is to be fuppos'd, that the heat of the three bodies will be the fame, as the heat of the water, however different they may be in fpecific gravity, &c. The whole difficulty is now reduc'd to this problem, *viz.*

To find the abfolute expanfion of the bafis between any two given degrees of heat, not greater than that of boiling water.

For this purpofe, let there be prepar'd a bar of ftrait-grain'd white deal, or cedar; which, it is well known, are much lefs expanfible by heat than any metal hitherto difcover'd: Let the bar be adapted to the inftrument in like manner as the other bars intended to be meafur'd; but that the foftnefs of the wood may not hinder the juftnefs of its bearings, let its ends be guarded with a bit of brafs let into the wood at the points of contact, to prevent, as much as may be, the moifture or fteam of the water from affecting the wood; let it firft be well varnifh'd, and then, being wrapp'd round with coarfe flax from end to end; this will, in a great meafure, imbibe the vapour, before it arrives at the wood. Let the ciftern alfo be fo contriv'd, that the inftrument being fupported at a proper height therein, the bar to be meafur'd may, upon occafion, be above the cover, while the bafis remains in the water: Thus will the cover

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alſo be a defence againſt the moiſture. Let the water in the ciſtern be now brought to its lower degree of heat (ſuppoſe at or near the freezing point), the baſis having continu'd long enough in the water to receive the ſame degree of heat, and the wooden bar having been previouſly kept in an adjacent room, not ſubject to ſudden alterations of temperature by fire, or other cauſes; let the bar be apply'd to the inſtrument, and the degrees of the micrometer and the thermometer read off, and ſet down: Let the wooden bar be then reſtor'd to its former place, till the water is heated to the greater degree intended (ſuppoſe at or near that of boiling water); the lid being now ſhut down, and the chinks ſtopp'd with coarſe flax, to prevent the iſſuing of the ſteam as much as poſſible, let the wooden bar be again brought forth apply'd to the inſtrument, and the degrees of the micrometer and thermometer read off, as before: The difference of degrees of the micrometer, correſponding to the difference of degrees of the thermometer, will expreſs the expanſion of the baſis between thoſe degrees of heat; that is, upon the ſuppoſition that the wooden bar was of the ſame length, at the time of taking the ſecond meaſure, as at the firſt: Indeed a meaſure can hardly be taken without any loſs of time, as the whole of the inſtrument, when the hot meaſure is to be taken, is conſiderably hotter than the wooden bar; and, in caſe of boiling water, the ſteam being very repellent and active, the bar is liable to be ſenſibly affected in its length, before the meaſure can be taken, both by heat and moiſture, which both tend to expand the bar: But as the quantity is ſmall, and capable

pable of being nearly aſcertain'd, a wooden bar, thus apply'd, will anſwer the ſame end as if it was unalterable by heat or moiſture.

In order, therefore, to know the quantity of this alteration, let the time elaps'd between the firſt approach of the bar to the inſtrument, and the taking of the meaſure, be obſerv'd by a ſecond-watch, or otherwiſe; after another equal interval of time, let a ſecond meaſure be taken; and after a third interval, a third; and a fourth; the three differences of theſe four meaſures will be found nearly to tally with three terms of a geometrical progreſſion, from which the preceding term may be known, and will be the correction; which, if apply'd to the meaſure firſt taken, reduces it to what it would have been if the wooden bar had not expanded during the taking thereof.

From a few obſervations of this kind, carefully repeated, the expanſion of the baſis may be ſettled; and this once done, the making experiments upon other bars will become very eaſy, and compendious.

The baſis of this inſtrument (as well as other parts thereof) is braſs. I choſe this ſubſtance rather than any other whoſe expanſion was greater or leſs, becauſe I found, from ſome groſs experiments previouſly made, that the expanſion of braſs was nearly a medium between thoſe bodies, which differ moſt in their expanſion: A conſiderable convenience ariſes from this circumſtance; becauſe as the meaſures, taken in common experiments, are their difference from braſs, the dependence upon the thermometer will be leſs, as theſe differences are leſs. This precaution I have found the more neceſſary, as the greateſt errors that experiments made with this inſtrument are ſubject to,

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feem to be chiefly owing to the thermometer, tho' that which I us'd was well graduated, and good in other refpects; but this muft neceffarily happen, as the fcale and fenfibility of the micrometer, when thofe metals were try'd which differ moft from the bafis, were greater than that of the thermometer.

The bar of brafs which compofes the bafis is an inch broad by half an inch thick, and ftands edge-ways upwards; one end is continu'd of the fame piece at right angles, to the height of three inches and an half, and makes a firm fupport for the end of the bar to be experimented; and the other end acts upon the middle of a lever of the fecond kind, whofe fulcrum is in the bafis; therefore the motion of the extremity of the lever is double the difference between the expanfion of the bar, and the bafis. This upper part of the lever rifes above the lid of the ciftern, fo that it and the micrometer-fcrew are at all times clear of the water. The top of the lever is furnifh'd with an appendage which I call the *feeler*; it is the extremity of this piece which comes in contact with the micrometer-fcrew. The conftruction and application hereof will better appear from the draught, than from many words. It hence appears, that, having the length of the lever from its fulcrum to the point of fufpenfion of the feeler, the diftance between the fulcrum and the point of contact with the bar, the inches and parts that correfpond to a certain number of threads of the micrometer, and the number of divifions in the circumference of the index-plate; the fraction of an inch exprefs'd by one divifion of the plate may be deduc'd: Thofe meafures are as follows.

From

	Inches.
From the fulcrum of the lever to the feeler	5.875
From the fulcrum to the plate of contact	2.895
Length of 70 threads of the ſcrew . .	2.455
Diviſions in the circumference of the index-plate 100.	

Hence the value of one diviſion will be the $\frac{10}{57863}$ part of an inch: But if the ſcrew be alter'd $\frac{1}{4}$ of one of theſe diviſions, when the contact between the ſcrew and feeler is well adjuſted, the difference of contact (if I may ſo call it) will be very perceivable to the ſlighteſt obſerver; and, conſequently, $\frac{1}{23145}$ part of an inch is perceivable in this inſtrument.

There is one thing ſtill remains to be ſpoke of, and that is, the verification of the micrometer-ſcrew, which is the only part of this inſtrument that requires exactneſs in the execution; and how difficult theſe are to make, perfectly good, is well known to every perſon of experience in theſe matters; that is, that the threads of the ſcrew may not only be equidiſtant, in different places, but that the threads ſhall be equally inclin'd to the axis in every part of the circumference.

As nearly the ſame part of the ſcrew is made uſe of in theſe experiments, the latter circumſtance is what principally needs enquiry. For this purpoſe, let a thin ſlip of ſteel, or other metal, be prepar'd, whoſe thickneſs is about $\frac{1}{8}$ of the diſtance of the threads: Let the edges of this thin plate be cut into ſuch a ſhape, as exactly to fit into the fix'd notch in which one end of the bar is laid: Let a ſcrew paſs thro' the ſtandard of braſs, on which that notch is

ſupported, in ſuch a manner, that the end of the bar to be meaſur'd that is fartheſt from the lever, may take its bearing againſt the point (or rather the ſmall hemiſpherical end) of this ſcrew: Let one of the braſs bars, us'd in the other experiments, be apply'd to the inſtrument, and a meaſure taken; then let the thin plate be put in between the end of the bar and the point of the ſcrew laſt mention'd, and again take the meaſure; but firſt obſerve, that the plate is put down to the notch, ſo that the ſame place of the plate may always agree with the point of the ſcrew, and, conſequently, no error may ariſe from a different thickneſs in different places of the plate: Obſerve alſo, that the whole comes to a true bearing; then advance the ſame ſcrew till the micrometer-ſcrew is puſh'd backward $\frac{1}{4}$ of a revolution; again repeat the meaſure with and without the thin plate; again advance the former ſcrew, ſo as to make that of the micrometer recede another quarter of a turn, and repeat the meaſures with and without the thin plate. This method being purſu'd as far as neceſſary, it is evident, that, the thickneſs of the plate being always the ſame, if the difference of meaſures, taken with and without it, are not always the ſame in the different parts of a revolution of the micrometer-ſcrew, that this ſcrew is not equiangular; but from the differences of the meaſures correſponding to the thickneſs of the ſame plate, in the different parts of a revolution, the errors thereof may be nearly aſſign'd. For greater certainty in this examination, leſt the heat of the obſerver's body ſhould affect the bar or inſtrument during the obſervation, let the whole be immerg'd in the ciſtern of water, which ought to ſtand a ſufficient time before

fore the observation is begun, to acquire the same temper as the air, which also ought to be in a settled state.

In this manner I examin'd such threads of this screw as were made use of in the following experiments, but did not find any material errors.

The result of the experiments made with this instrument agrees very well with the proportions of expansion of several metals given by Mr. Ellicott; which were deduced from his pyrometer publish'd in the *Philosophical Transactions:* And, considering the very different construction of the two instruments, they abundantly tend to confirm each other.

References to the Figures.

Fig. 1. represents the instrument independent of the cistern in which it is us'd.

A B C D, is the main bar or basis of the instrument.

E F, is the bar to be measur'd, lying in two notches; one fix'd to the upright standard *A B*, the other to the principal lever *H I*. The end *E* of the bar *E F*, bears against the point of

G, a screw of use in examining the micrometer-screw.

The other end of the bar *F* bears against a small spherically protuberant bit of hard metal fix'd at the same height as *G*, in the principal lever *H I*.

K, is an arbor fix'd in the basis, which receives at each end the points of the screws *H L*, upon which the lever *H L* turns, and serve as a fulcrum thereto.

O, is a slender spring, to keep the lever in a bearing state against the bar; and

P, is a check, to prevent the lever from falling forward when the bar is taken out.

N, is the feeler, ſomething in the ſhape of a T, ſuſpended, and moveable up and down upon the points of the ſcrews *I M*, which, as well as *L H*, are ſo adjuſted, as to leave the motion free, but without ſhake.

Q R, is the handle of the feeler, moveable upon a looſe joint at *R*; ſo that, laying hold of it at *Q*, the feeler is mov'd up and down without being affected by the irregular preſſure of the hand.

The extremity *s* of the feeler is alſo furniſh'd with a bit of protuberant hard metal, to render its contact with the point of the micrometer-ſcrew more perfect.

I, is the micrometer-ſcrew; *V*, is the divided index-plate, and *W*, a knob for the handle.

The micrometer-ſcrew paſſes thro' two ſolid ſcrew'd holes at *D* and *Y*.

The piece *Y Z* is made a little ſpringy, and endeavours to pull the ſcrew backwards from the hole at *D*; of conſequence keeps the micrometer-ſcrew conſtantly bearing againſt its threads the ſame way, and thereby renders the motion thereof perfectly ſteady and gentle.

X, is the index, having diviſions upon it, anſwering to the turns of the ſcrew. This piece points out the diviſions of the plate, as the face of the plate points out the diviſors upon the index.

When the inſtrument is us'd, lay hold of the knob at *Q* with one hand, and, moving the feeler up and down, with the other move forward the ſcrew *I*, till its

its point comes in contact with the feeler; then will the plate and index *V* and *X* ſhew the turns, and parts.

Fig. 2. repreſents the inſtrument immerg'd in its ciſtern of water, ready for uſe.

A B, is the ciſtern; *C*, the cover; which, when the inſtrument *fig.* 1. is rais'd upon blocks, goes on between the bar *E F* and the baſis *B C*.

D, a handle to take off the cover, when hot; *E*, the mercurial thermometer; *F*, the cock to let out the water.

G H, a hollow piece of tin, which ſupports ſeven ſpirit lamps, which are rais'd higher or lower by the ſcrews *I* and *K*, in order to give the water in the ciſtern a proper degree of heat.

A TABLE of EXPERIMENTS,

By which the numbers in Tab. I. Col. 6. N° 1, 2, *and* 4, *were determin'd.*

Experiment 1. The time elaps'd between approaching the bar to the inſtrument and taking the firſt meaſure, was half a minute: Therefore the intervals between taking the ſucceeding meaſures was half a minute alſo. The firſt meaſure was 208; the ſecond $214\frac{1}{2}$; the third $216\frac{1}{2}$; the fourth $217\frac{1}{2}$. The differences of theſe are $6\frac{1}{2}$, 2, and 1; which pretty well tallies with the three laſt terms of the following geometrical progreſſion whoſe common diviſor is 2.8; *viz.* 17.7 : 6.3 : : 2.25 : .8; therefore as the meaſures increas'd from the firſt, the firſt meaſure being diminiſh'd by the firſt term, *viz.* 208 — 17.7 = 190.3, will

will be the true meaſure of the bar at the firſt inſtant of its application, before it was expanded by the heat and moiſture about the inſtrument.

Exp. 2. The firſt meaſure was $221\frac{1}{4}$; the ſecond, 227; third, $230\frac{1}{2}$; fourth, $232\frac{3}{4}$; whoſe differences are $5\frac{3}{4}$, $3\frac{1}{2}$, and $2\frac{1}{4}$; agreeing with the three laſt terms of the following progreſſion, whoſe common diviſor is 1.6; *viz.* 9.2 : 5.8 :: 3.6 : 2.2; therefore $221.25 - 9.2 = 212.15$.

Exp. 3. The firſt meaſure taken was 401; and at that degree of heat the wooden bar did not ſenſibly alter during two minutes.

Exp. 4. The firſt meaſure taken was $275\frac{1}{2}$; ſecond, $278\frac{1}{2}$; third, $280\frac{3}{4}$; and the fourth, $282\frac{1}{4}$: The differences are, 3, $2\frac{1}{4}$, $1\frac{1}{2}$; agreeing with the three laſt terms of the following progreſſion, whoſe common diviſor is 1.43; *viz.* 4.4 : 3.1 :: 2.15 : 1.5; therefore $275.5 - 4.4 = 271.1$, which is the firſt meaſure corrected.

Hence, as appears by *Tab.* I. N° 1, 2, 3, and 4, Column 9. theſe experiments being properly reduc'd, agree within one diviſion of the micrometer; and the expanſion of the baſis, at a medium, is $287\frac{1}{2}$ parts thereof; correſponding to 166° of Farenheit's thermometer.

TABLE

TABLE II.

A TABLE of Expanſions of Metals,

Shewing, how much a foot in length of each, grows longer by an increaſe of heat correſponding to 180 degrees of Farenheit's thermometer, or to the difference between freezing and boiling water, expreſs'd in ſuch parts whereof the unit is equal to the 10000th part of an inch.

1	White glaſs barometer-tube.	100
2	Martial regulus of antimony.	130
3	Bliſter'd ſteel.	138
4	Hard ſteel.	147
5	Iron.	151
6	Biſmuth.	167
7	Copper hammer'd.	204
8	Copper 8 parts, mix'd with tin 1.	218
9	Caſt braſs.	225
10	Braſs 16 parts, with tin 1.	229
11	Braſs wire.	232
12	Speculum metal.	232
13	Spelter ſolder, *viz.* braſs 2 parts, zink 1.	247
14	Fine pewter.	274
15	Grain tin.	298
16	Soft ſolder, *viz.* lead 2, tin 1.	301
17	Zink 8 parts, with tin 1, a little hammer'd.	323
18	Lead.	344
19	Zink or ſpelter.	353
20	Zink hammer'd half an inch per foot.	373

P. S.

P. S. It is now ſeveral years ſince I firſt obſerv'd the very conſiderable expanſion of the ſemi-metallic ſubſtance call'd *zink*, *ſpelter*, or *tootanag*; and propos'd it as more fit for the purpoſe of making compound pendulums, and metalline thermometers, than braſs; as its expanſion ſeem'd conſiderably greater, and its conſiſtence, when gently hammer'd, not much inferior. With the ſame view I have made trial of ſeveral other metallic compoſitions, beſides what is above ſet down; but they all prov'd much inferior to zink in expanſion, and moſt of them in conſiſtence.

It ſeems, that metals obſerve a quite different proportion of expanſion in a fluid, to what they do in a ſolid ſtate: For regulus of antimony ſeem'd to ſhrink in fixing, after being melted, conſiderably more than zink.

FINIS.

TAB. I. A TABLE of Experiments.

No	Matter of the Bars.	Cold Measure. Parts of Micrometer.	Cold Measure. Deg. by Thermom.	Middle Measure. Parts of Micrometer.	Middle Measure. Deg. of Thermom.	Hot Measure. Parts of Micrometer.	Hot Measure. Deg. of Thermom.	Extremes. Different Parts.	Extremes. Diff. Thermom.	Extremes. Diff Pts reduced to 166°.	Cold and Mediums. Different Parts.	Cold and Mediums. Diff. Thermomet.	Cold and Mediums. Diff. Pts reduced to 66°.	Mean Pts deduced from Extremes.	Irregularity.
1	Standard bar of white deal — — —	486.3	40½	— —	— —	190.3	211½	—296.0	171	287.0	— —	—	— —	— —	— —
2	— — — — repeated	495.8	47½	— —	— —	212.1	211	—283.7	163½	288.0	— —	—	— —	— —	— —
3	— — — — repeated	514.6	43½	401.0	109	— —	— —	— — —	— —	287.0	113.6	65½	114.5	— —	— —
4	— — — — repeated	573.1	37	— —	— —	271.1	211½	—302.0	174½	288.0	— —	—	— —	— —	— —
5	White glass barometer tube — — —	625.0	39½	569.0	96½	500.5	163	—124.5	123½	167.5	56.0	57	65.0	66.5	+1½
6	— — — — repeated	566.6	39	— —	— —	406.3	206	—160.3	167	159.5	— —	—	— —	— —	— —
7	— — — — repeated	557.1	47	494.7	112	398.0	208	—159.1	161	163.5	62.4	65	63.3	65.0	+1½
8	Martial regulus of antimony — — —	684.1	47	— —	— —	560.0	210	—124.1	163	126.1	— —	—	— —	— —	— —
9	— — — — repeated	751.0	39½	708.0	95½	662.5	154	— 88.5	114½	128.0	43.0	56	50.7	51.0	+ ¼
10	Blister'd steel — — — —	685.7	40	— —	— —	564.9	210	—120.8	170	118.2	— —	—	— —	— —	— —
11	— — — — repeated	683.8	47	638.0	113½	566.3	210½	—117.5	163½	119.0	45.8	66½	45.5	47.4	+2
12	Another bar from the same gad — — —	719.7	40	— —	— —	599.5	210	—120.2	170	117.5	— —	—	— —	— —	— —
13	Another bar from a different gad — — —	740.1	40½	— —	— —	622.3	210½	—117.8	170	115.5	— —	—	— —	— —	— —
14	— — — — repeated	739.9	47	694.0	114	625.0	209	—114.9	162	117.5	45.9	67	45.1	46.7	+1½
15	Steel harden'd — — — —	904.5	37¾	855.5	113½	795.2	210	— 109.3	172¼	105.3	49.0	75¾	42.7	41.9	—1
16	Dantzick iron — — — —	697.5	40½	— —	— —	593.5	211½	—104.0	171	101.0	— —	—	— —	— —	— —
17	Another bar from the same gad — — —	705.8	40½	— —	— —	604.5	210½	—101.3	170	99.0	— —	—	— —	— —	— —
18	Another bar from a different gad — — —	683.9	40½	— —	— —	580.3	210½	—103.6	170	101.0	— —	—	— —	— —	— —
19	— — — — repeated	683.5	47	642.9	114	583.1	209	—100.4	162	102.5	40.6	67	40.0	40.8	+ ¾
20	Thick wire of English iron — — —	756.0	40	— —	— —	653.6	209	— 102.4	169	101.0	— —	—	— —	— —	— —
21	Another rod from the same piece — — —	694.9	40	— —	— —	593.6	207	—101.3	167	101.0	— —	—	— —	— —	— —
22	Bismuth, or tin-glass — — — —	689.6	39	— —	— —	606.0	211	— 83.6	172	80.7	— —	—	— —	— —	— —
23	Copper plate hammer'd — — —	542.1	40	— —	— —	511.1	205	— 31.0	165	31.2	— —	—	— —	— —	— —
24	— — — — repeated	605.0	39½	593.5	94¾	582.0	142	— 23.0	102½	37.2	11.5	55¼	13.7	14.8	+1
25	Another bar from the same piece — —	660.0	39½	— —	— —	627.1	203	— 32.9	163½	33.4	— —	—	— —	— —	— —
26	— — — — repeated	717.0	39¾	705.0	93½	694.5	139¾	— 22.5	100	37.3	12.0	53¾	14.7	14.8	+ $\frac{1}{10}$
27	Copper 8 parts, with tin 1 — — —	721.0	47	715.0	111½	703.7	209	— 17.3	162	17.7	6.0	64½	6.1	7.0	+1
28	Cast brass hammer'd — — — —	581.1	39½	— —	— —	571.8	210	— 9.3	170½	9.1	— —	—	— —	— —	— —
29	— — — — repeated	584.2	47	582.0	112½	575.0	208½	— 9.2	161½	9.5	2.2	65½	2.2	3.8	+1½
30	The same brass unhammer'd — — —	682.4	39½	— —	— —	673.5	210	— 8.9	170½	8.7	— —	—	— —	— —	— —
31	Thick brass wire hard drawn — — —	691.2	39½	— —	— —	691.0	210	— 0.2	170½	0.2	— —	—	— —	— —	— —
32	— — — — repeated	694.5	47	695.5	112½	692.3	209½	— 2.2	162½	2.2	1.0	65½	1.0	0.9	— $\frac{1}{10}$
33	Brass wire softer drawn — — —	741.1	39½	— —	— —	741.1	210	0.0	170½	0.0	— —	—	— —	— —	— —
34	Speculum metal — — — —	827.7	47	828.8	112	826.5	208½	— 1.2	161½	1.2	1.1	65	1.1	0.5	— ½
35	Brass 16 parts, with tin 1 — — —	603.7	47	602.5	111½	597.6	209	— 6.1	162	6.3	1.2	64½	1.2	2.5	+1¼
36	Speltre solder, *viz.* brass 2, zink 1 — —	615.0	47	624.2	111½	632.5	209	+ 17.5	162	17.9	9.2	64½	9.4	7.1	—2¼
37	Fine pewter — — — — —	743.3	47	764.0	109½	793.8	211	+ 50.5	164	51.1	20.7	62½	21.8	20.4	— 1½
38	Grain tin — — — — —	742.4	47	767.1	115	818.2	209	+ 75.8	162	76.8	24.7	68	24.0	30.5	+6½
39	— — — — repeated	735.5	39	— —	— —	822.6	210	+ 87.1	71	84.5	— —	—	— —	— —	— —
40	Soft solder, *viz.* lead 2, tin 1 — — —	681.7	47	713.0	114	765.0	210	+ 83.3	163	84.7	31.3	67	30.8	33.7	+3
41	Zink, 8 parts, tin 1, lightly hammer'd — —	753.5	38¾	797.5	105	826.5	147	+ 73.0	108¼	111.8	44.0	66¼	43.9	44.4	+ ½
42	Hard lead — — — — —	569.5	39	— —	— —	721.7	211	+152.2	172	147.2	— —	—	— —	— —	— —
43	— — — — repeated	617.7	47	664.5	110	753.0	211	+135.3	164	136.5	46.8	63	49.0	54.3	+5¼
44	Soft lead — — — — —	552.7	47	609.3	110	680.7	211	+128.0	164	129.5	56.6	63	59.2	51.5	—7¾
45	Zink, or speltre — — — —	654.9	39	— —	— —	810.0	211½	+155.1	172½	149.0	— —	—	— —	— —	— —
46	— — — — repeated	665.6	47	723.5	114½	812.0	210	+146.4	163	149.0	57.9	67½	56.5	59.4	+3
47	Zink hammer'd out half an inch a foot — —	628.0	38¼	693.0	106½	744.5	150	+116.5	111¾	173.0	65.0	68¼	63.0	68.9	+6

Place this between p. 610, 611.

Fig. 1. p. 608.

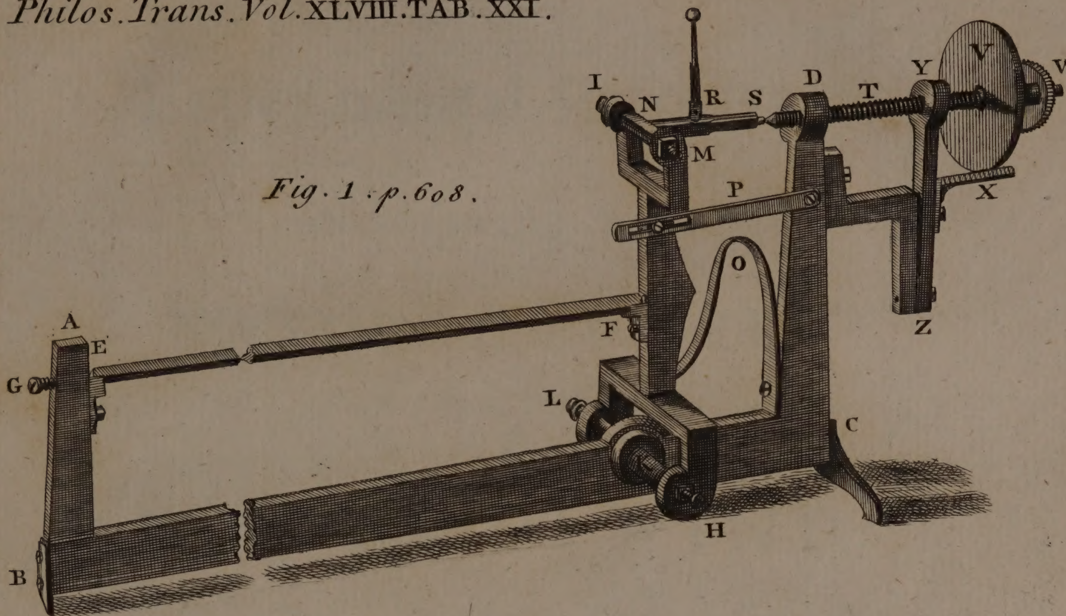
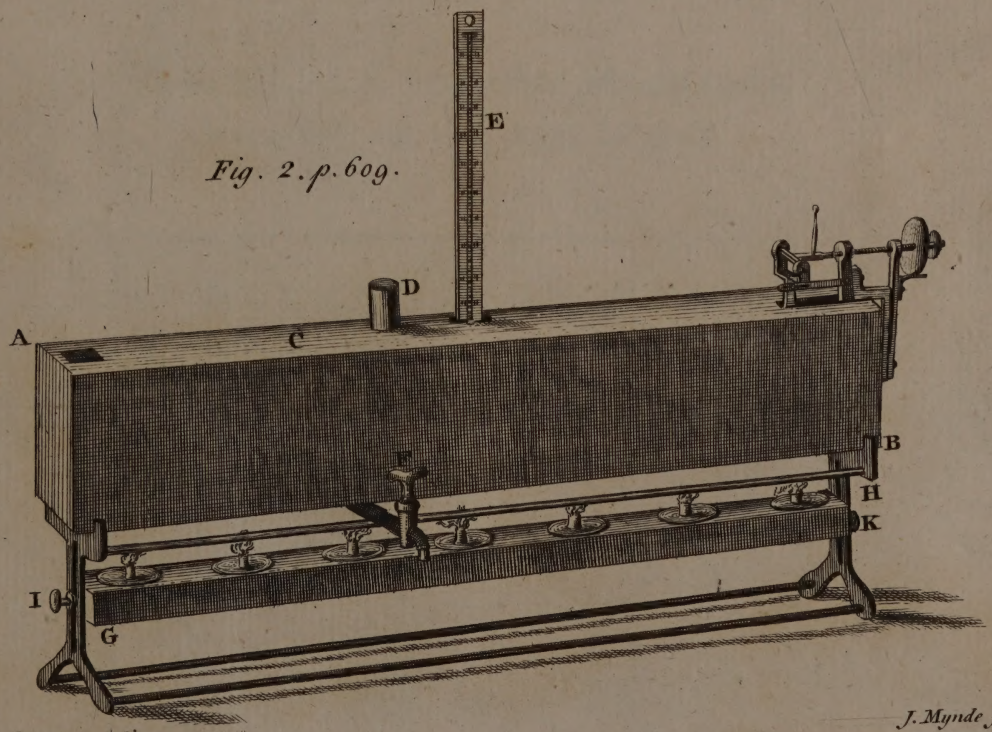


Fig. 2. p. 609.



J. Smeaton delin.

J. Mynde sculp.